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Logistics Scheduling Model of Cold Rolling Intermediate Storage Based on Hybrid Flow Shop Principle

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Abstract:

With the rapid development and application of Intelligent Logistics technology in metallurgical production, in recent years, a kind of intermediate warehouse transportation system in steel plant, represented by Railroad Mother Nested Multi-Car System, has gradually appeared, which effectively solves the drawbacks of crane lifting in the intermediate warehouse area and improves the transportation efficiency of shop-level logistics. However, at present, the scheduling strategy research of this kind of multi-vehicle cooperative transportation unit has been carried out. There are not many applications, which is also a bottleneck for the intelligent control of this kind of multi-vehicle transportation system. In this paper, aiming at the characteristics of the cross-composite configuration of multiple subcars and mothercars in the logistics transportation system of intermediate warehouse, the joint operation scenario of accessing and accessing cold rolled intermediate warehouse coils is analyzed, and the detailed decomposition is made, the system operation rules and boundary conditions are formulated, and the process iteration based on mixed flow shop is established.The mathematical model of system dispatch optimization based on the principle is obtained, and the objective function of optimizing the dispatch of sub-parent vehicles in the intermediate warehouse logistics system is obtained. Therefore, it provides a practical theoretical basis for the intelligent control of this kind of child parent multi vehicle logistics system and improving the equipment operation efficiency, especially for the logistics scheduling planning in the reservoir area of metallurgical heavy load field.

Keywords: *Railway Multi-Car Transport System; Coil Access Job; Hybrid Flow Shop; Scheduling Objectives Function*

I. INTRODUCTION

In <Made in China 2025> the promotion and application of intelligent technology in manufacturing industry is clearly emphasized. How to use intelligent technology to improve logistics production scheduling capacity in metallurgical heavy haul field has important practical significance [1]. In recent years, the multi-mode and flexible control decision-making system of the combination of coil conveying

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sub vehicle and parent vehicle in the intermediate warehouse of steel plant is a kind of production logistics scheduling system in urgent need of intelligent scheduling control. It is very important for the efficient operation of the whole conveying system to formulate a reasonable system operation scheduling strategy. At present, the research on workshop level intelligent storage logistics scheduling optimization mainly focuses on the scheduling model of traditional stacker in three-dimensional warehouse [2]. Liu et al. [3] designed the shelf as the access scheduling unit to distinguish different storage areas, and configured a stacker in each area to be responsible for the access scheduling task in this area; Xu et al. [4] studied the automatic storage location access scheduling management system of three-dimensional warehouse, and emphasized the matching relationship and principle between storage location management and transportation scheduling; Kung et al. Studied the scheduling planning of the material access system of track multi stacker in the manufacturing industry, but the established scheduling model is only limited to the form that one stacker matches several roadway trolleys [5]. Most of the three-dimensional warehouse stacker scheduling systems studied in the above relevant literature do not have the scheduling mode of flexible cross combination of multiple vehicles, and their scheduling model and path mode are not suitable for the transportation scheduling system with cross nested compound cooperative operation of multiple sub vehicles and multiple parent vehicles studied in this paper. As one of the classical production scheduling, hybrid flow shop scheduling can establish scheduling for multiple objectives due to its iterative characteristics, and is also suitable for establishing more complex scheduling models. At present, relevant literatures include: Wang Chun and others have constructed a flexible job shop scheduling model with the optimal objectives of minimum area, maximum completion time and total machine load [6]; Zhou et al. Studied the hybrid flow shop scheduling problem with the goal of minimizing total energy consumption and maximum completion time [7]; Wang et al. Tried to establish a flexible job shop scheduling problem for each machine under specific constraints [8]; Huang et al. Studied the flow shop scheduling problem for two-level processor maintenance operation [9]; Chen et al. Studied the flexible job shop scheduling of repeated access process for parallel machines [10]. In the above literature, the flexible flow shop scheduling is mostly aimed at single objective optimization, and there is little research on the multi-objective optimization problem of steel mill intermediate warehouse logistics system studied in this paper. This paper attempts to take the shortest distance and fastest time of the path planning of the intermediate warehouse logistics system of the steel plant as the optimization goal to solve the problem of cross hybrid configuration and compound scheduling of sub vehicle and parent vehicle. Through the formulation of optimization models under different constraints, the optimal path of access and picking is obtained to minimize the operation time or running distance of the whole system. A scheduling model of multi vehicle transportation system of steel plant intermediate warehouse based on the principle of hybrid flow shop is established, and its effectiveness and feasibility are verified by simulation.

II. SYSTEM SCHEDULING PROBLEM DESCRIPTION

The job scheduling problem of the steel coil conveying system in the intermediate warehouse of the steel plant studied in this paper is how to find the most reasonable route or the shortest path in the system job transportation network diagram given the starting point and end position of the conveying carrier, so that the conveying carrier can walk according to the predetermined path under the condition of normal

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operation. For this system, when the task is triggered, it is necessary to plan the vertical travel path for each child vehicle in the idle state, and also plan the route of the parent vehicle in the horizontal direction of multiple main channels, that is, select the appropriate parent vehicle to complete the horizontal operation of the main channel, and finally improve the operation efficiency of the whole logistics system through the reasonable and efficient cooperative operation between the child and parent vehicles.

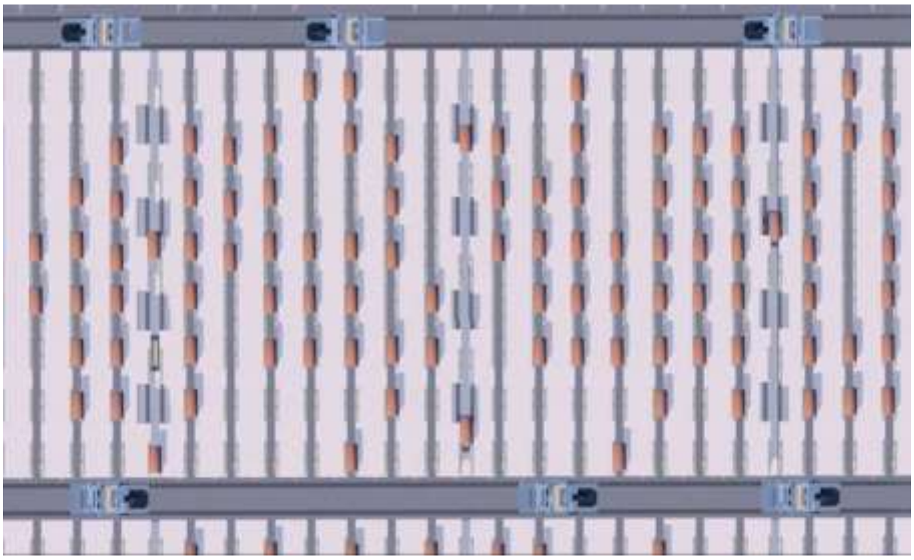

Fig 1: partial diagram of multi-channel operation network path of intermediate warehouse logistics transportation

As shown in Figure 1, it is the multi-channel operation network partial diagram of logistics transportation in the intermediate warehouse of the cold rolling operation area of the steel plant, including four horizontal main channels and several cache sub vehicle channels, and all cache areas for accessing steel coils in the whole system are connected in series through these four main channels. The steel coil saddle cargo space of each cache channel in the cache area is both the starting point and the end point of the logistics transportation path, By coding the addresses and tasks of all starting points and end points of the transportation system, and selecting a reasonable combination of parent and child vehicles and path channels according to the principle of proximity and the principle of shortest time, we can complete the path optimization scheduling of the intermediate warehouse logistics transportation system [11]. In this way, we first need to analyze the operation mode and type of the transportation carrier of the whole logistics system, and specifically analyze the operation type of the system, the characteristic constraints of system scheduling are obtained, and the corresponding operation rules are formulated. Then these characteristic parameters are used as the constraints of the path planning algorithm to establish the scheduling model function. The main operation types of intermediate warehouse logistics transportation system are: coil storage operation, coil take-up operation and coil access operation. Coil storage operation refers to that multiple parent cars transport the steel coil from the interface between the main line unit and logistics or the buffer saddle cargo space to the destination saddle cargo space allocated to the steel coil; The coiling operation refers to that the steel coil is transported from the storage saddle cargo space to the interface between the packaging unit and the logistics, or to the interface between the rewinding unit and

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the logistics; When there are volume access operation instructions in the system at the same time, multiple child parent vehicles will carry out composite operation to complete the operation task, that is, the child parent vehicle adopts the operation mode of cross volume access, first executes the volume removal operation, and then executes the volume storage operation.

III. CONFIGURATION PRINCIPLE BASED ON FLOW SHOP SCHEDULING MODEL

The optimization of system scheduling problem is usually the process of allocating system resources to achieve the optimal operation of system objectives. For flow shop, it is to determine the processing order of workpieces. Therefore, scheduling problem is sometimes considered as production scheduling problem, which is widely used in flexible job scheduling [12]. According to the previous analysis, for the transportation system, the scheduling of multiple sub vehicles and parent vehicles is the coordinated allocation of sub vehicles and parent vehicles to achieve the optimal allocation of system resources. In fact, it can also be regarded as the sequential scheduling problem of sub vehicles and parent vehicles. The problem of flow shop scheduling refers to that n products to be processed are processed in M processes on the assembly line, and each process has several machines for operation. The products to be processed can be selected randomly or designated in each process, and the whole processing time of all processed products can be found to be the shortest or the processing order is the best through the arrangement and combination of different processing sequences.

Therefore, the key links and stages in the logistics transportation system studied in this paper can be regarded as the corresponding objects to be optimized in flow shop scheduling, that is, the steel coils to be accessed in this system correspond to the products to be processed, the cache sub car and the main channel parent car are regarded as processing machines, and the different stages of operation are regarded as different processes. For each steel coil to be accessed, the cache sub car and main channel parent car in different stages will take different time and distance. That is, the total distance or time spent on the steel coil to be accessed going through s stages and carrying M sub cars and N parent cars will be taken as the optimization objective problem, which will be transformed into the workshop scheduling problem of multi-stage F + T parallel machines processing C parts. The evaluation indexes of flow shop scheduling scheme include: total process time (makespan), average process time, maximum delivery delay, number of delayed workpieces, average product inventory and cost indexes. Here, the system scheduling model is established based on the total process time and the shortest distance of workshop scheduling.

For the multi sub vehicle and multi parent vehicle scheduling of the logistics system studied in this paper, it can be seen from the previous section that stage 1 is the scheduling task allocation of the cache sub vehicle, that is, select the delivery unit sub vehicle for accessing the steel coil, and then enter the second stage for the scheduling task allocation of the main channel parent vehicle. The scheduling of the cache sub vehicle and the main channel parent vehicle is regarded as a parallel processing machine that is not directly related to each other. Each access task will schedule the cache sub car at least once, but for the master car scheduling of the main channel, there is no need to call the master car when it does not cross the cache channel, and its scheduling weighting times is zero. There is also a process of multi car handover

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when the steel coil is transferred relay across multiple channels. The flow shop scheduling rules require each product to complete the selection of processing machines at each stage, the process of each job is the same, so the concept of hybrid flow shop scheduling needs to be introduced. Hybrid flow shop scheduling problem (hfssp), also known as flexible flow shop scheduling problem, is an extension of classical flow shop scheduling. It combines the characteristics of classical flow shop and parallel machine scheduling, which is very in line with the requirements of sequential and joint parallel scheduling of actual logistics operations in this paper. After reasonable optimization, it has a good fit, and can well solve the multi cross, multi type and out of order logistics scheduling problem in the system studied in this paper.

IV. TRANSFORMATION OF HYBRID FLOW SHOP SCHEDULING MODEL

The scheduling optimization objective of hybrid flow shop is how to determine the processing sequence of workpieces and the allocation of workpieces in each stage on the machine, so as to minimize the maximum completion time [12]. Therefore, the scheduling optimization goal of the logistics transportation system is: how to determine the transportation sequence of steel coil in the logistics system and how to allocate multi-channel parent vehicle and cache sub vehicle at each stage of accessing steel coil.

For hybrid flow shop scheduling, the following conditions need to be constrained: each operation can only be processed by one machine at a time; The processing time of each process varies from machine to machine, and different machines are independent of each other; Each processing procedure cannot be interrupted; The machine preparation time for processing a workpiece has been considered in the corresponding processing time; The transfer time of workpieces between different machines has been considered in the processing time. Similarly, it can be obtained that the scheduling conversion constraint assumptions of the logistics transportation system are as follows:1) All transport trolleys are the same in the same stage; 2) Each steel coil can be transported on any sub car or mother car at a certain stage; 3) At any time, each steel coil can only be transported on one sub car or parent car; 4) Each sub car or parent car can only transport one steel coil at a time; 5) The process of steel coil transportation shall not be interrupted.

For the actual production process, the hybrid flow shop scheduling optimization mainly considers the maximum completion time performance index Cmax (makespan), which aims to allocate each workpiece to a suitable machine for processing and sort the processing sequence of the machine, so as to minimize the maximum completion time Cmax for completing all workpiece processing tasks [13]. Then, the optimization objective of the logistics transportation system transformed into this paper is to allocate each steel coil to be accessed to its own appropriate sub vehicle and parent vehicle for transportation and storage, and optimally sort the sub parent vehicles involved in transportation in all stages, so as to minimize the maximum completion time Cmax for completing the steel coil transportation task.

Therefore, for the flexible operation scheduling problem of n coils to be accessed and m conveying sub parent vehicles, it is necessary to set Ci as the transportation completion time of coil Ji, and the objective

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function of the minimum value of the maximum transportation completion time Cmax is Cmax = min {Max Ci, i=1,... n}. As shown in Fig. 2, there are m processing stages from the beginning to the end. There are multiple parallel machines in each processing stage. The workpieces to be processed pass through each processing stage in turn. In each processing stage, they can be processed by any equipment in this stage [14].

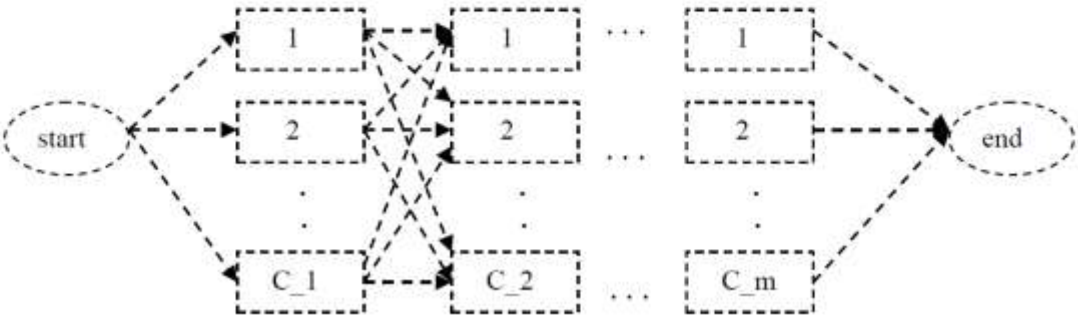

Fig. 2 Schematic diagram of job scheduling in hybrid flow shop

The operation scheduling of the steel coil logistics conveying system in the intermediate warehouse is converted according to the operation scheduling diagram of the mixed flow shop, which is divided into: single coil storage / retrieval task operation scheduling; Compound operation scheduling of steel coil access. As shown in Figure 3, the single operation scheduling diagram of the intermediate warehouse logistics transportation system. When the system performs the coil storage / retrieval operation task, the M sub vehicle and N parent vehicles carry out circular operation. Each operation task goes through two stages, stage 1 is the sub vehicle task allocation stage, and stage 2 is the parent vehicle task allocation stage. Because different sub vehicles and parent vehicles experience different paths, the sub vehicle or parent vehicle in each stage makes the optimal selection according to the algorithm results to obtain the job scheduling with the shortest distance or time to complete all tasks.

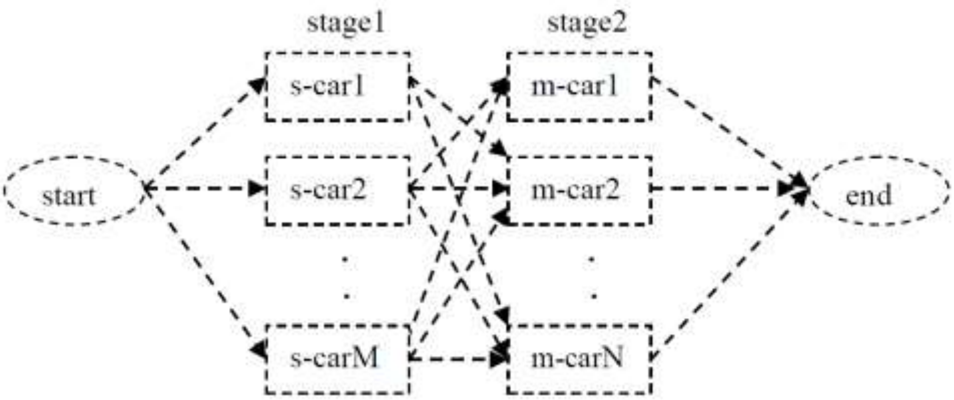

Fig. 3 single operation scheduling diagram of intermediate warehouse logistics transportation system

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Fig. 4 is a schematic diagram of the access compound operation scheduling of the intermediate warehouse logistics transportation system. For the compound operation mode of system storage before retrieval or retrieval before storage, the construction scheduling process is similar to a single coil storage / retrieval operation. Stage 1 is the sub vehicle task allocation stage, and stage 2 is the parent vehicle task allocation stage, but it will go through the third stage to reassign the sub vehicle. Therefore, the scheduling of composite operation task of steel coil access is only one more time than that of single task, and there is no change in the system scheduling structure.

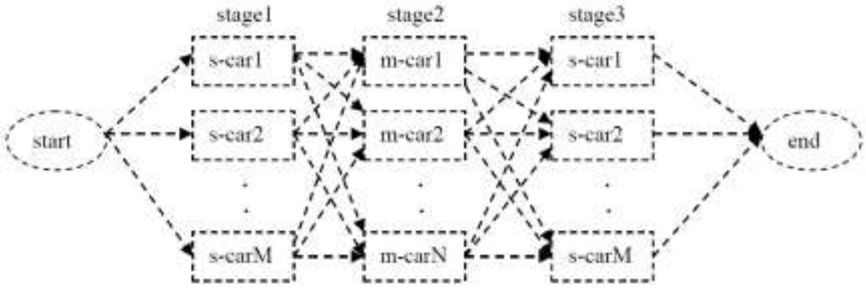

Fig. 4 schematic diagram of compound operation scheduling of intermediate warehouse logistics transportation system

V. ESTABLISHMENT OF OPTIMAL SCHEDULING MODEL BASED ON SHORTEST TIME

According to the idea of flow shop scheduling iteration, the scheduling model of the system is established: the first process is processed, and the corresponding workpieces are processed in turn on the idle machine according to the sequence of workpieces in the code; When processing the second process, according to the principle of "finish first, process first", the currently available workpieces are preferentially processed on the idle machine (the processing has been completed in the previous stage), and so on until the last workpiece ends in the last stage.

$$C\ (i1,\ 1)\ =P\ (1,\ 1); \tag{1}$$

$$C\ (ik,\ 1) = C\ (ik-1,\ 1) + P\ (k,\ 1); \tag{2}$$

$$C\ (i1,\ j) = C\ (i1,\ j-1) + P\ (1,\ j); \tag{3}$$

$$C\ (ik,\ j) = \max\{C\ (ik-1,j),\ C\ (ik,j-1)\}+P(k,j); \tag{4}$$

The formula (1) represents the processing time of the first operation of the first workpiece, which is equal to the completion time of the workpiece in the first stage; The formula (2) indicates the completion time of the k-th operation of the first workpiece, which is equal to the completion time of the previous operation of the workpiece plus the processing time of the current k operation; The formula (3) represents the completion time of the first process of workpiece j, which is equal to the completion time of the first process of previous workpiece on the same machine plus the processing time of the first process of

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workpiece j; The formula (4) represents the completion time of workpiece j in stage k, which is equal to the maximum value of the completion time of the process before workpiece J or the completion time of workpiece j-1 before the same machine plus the processing time of workpiece j in stage k. Through the above iterative analogy, we can get the objective function: makespan = min {C (mc, n)}. That is, the minimum value of the processing completion time of the last workpiece, that is, the minimum makespan of the whole task. The principle is transformed into that the intermediate warehouse logistics transportation system can be divided into two parts: horizontal movement and vertical movement when executing the movement path of storage / retrieval single operation task and access composite operation task:

Movement path perpendicular to the main channel of the system logistics: the movement path of the sub vehicle in the buffer area is perpendicular to the main channel of the system logistics, which can be divided into three cases: (1) the operation time of the sub vehicle moving from the current position to the interface between the buffer channel and the main channel is TZ1, (2) the operation time of the sub vehicle moving from the parent vehicle to the saddle of the target cargo location is TZ2, (3) If the current location of the child car and the target node are in the same cache channel, the running time is TZ3. Therefore, the total logistics operation time in the vertical direction is TZ = TZ1 + TZ2 + TZ3. In the third case, TZ1 and TZ2 are equal to 0; when it is not the third case, TZ3 is equal to 0.

It can be seen from the previous section that the difference between a single job and a composite job is that the composite job has more secondary scheduling of sub cars in the third stage than a single job. Therefore, a multi-stage job objective function can be established to uniformly express the single job and composite job. Therefore, according to the flow shop scheduling principle and based on the scheduling iteration formula, the vertical path objective function of the logistics system is obtained:

$$makespan = min\{C(m_c, n)\} = min \sum_{s=1}^{3} \left(tz_{s,i,a,b} + tz_{s,i,b,a} + tz_{s,i,a}\right) \quad (5)$$

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s: Number of operation stages;

a: Sub car number, value range (1, m);

b: Parent vehicle number, value range (1, n);

i: Job task number, value range (1, c);

tzs, i, a, b: The time taken by the a-th sub vehicle loading the i-th operation task from the current position to the parent vehicle interface position in phase s is TZ1. If the parent vehicle is not required to enter the sub vehicle in this phase, this value is 0;

tzs, i, b, a: The time taken by the a-th sub vehicle loading the i-th operation task from the parent vehicle interface position to the target position in phase s, i.e. TZ2; If the parent vehicle does not need to enter the child vehicle at this stage, this value is 0;

tzs, i, a: The time taken to load the a-th sub vehicle of the i-th operation task from the current position to the cargo space saddle of the target node in phase s is TZ3. If the parent vehicle is required to load the sub vehicle in this phase, this value is 0;

Constraint condition:

(1) Each task can only have one priority, pg, I is priority serial number:

$$\sum_{g=1}^{c} p_{g,i} = 1; i = 1,2 \ldots c \tag{6}$$

(2) Use of mother car in each stage: us, a, b=1, Sub car a uses parent car b in phase s; otherwise us, a, b =0;

(3) Each sub car can only occupy one parent car at the same stage:

$$\sum_{b=1}^{n} u_{s,a,b} = 1; i = 1,2 \ldots c; s = 1,2,3 \tag{7}$$

Moving path parallel to the direction of the main logistics channel of the system, that is, the time spent on the operation path of the parent vehicle moving on the main channel at each stage. Since several parent vehicles exist at the same time and transport together on the main logistics channel, it is necessary to consider the mutual movement of the parent workshop, avoidance and empty vehicle movement, The total time of horizontal moving path shall be composed of no-load moving time and loading moving time of parent vehicle. TM1 is the time taken for the parent train to run from the current position to the interface position of the child train, that is, the no-load operation time of the parent train; TM2 is all the time when the parent vehicle carries the sub vehicle to the target interface position, that is, the loading operation time

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of the parent vehicle; TM3 is the parent vehicle safety detection time, avoidance waiting time, etc. Therefore, the total horizontal movement time TM = TM1 + TM2 + TM3, but the complexity of scheduling optimization is greater than that of sub vehicle scheduling of vertical movement path. As shown in Figure 5, the two ends of the main channel of the intermediate warehouse logistics system are closed. When multiple parent vehicles are transported on the same track of the main channel, they may need to start, stop, accelerate and decelerate repeatedly. The scheduling operation has the characteristics of randomness, complex constraints and multi-objective conflict. It is necessary to solve the traffic jam and wait for each other by optimizing the scheduling to improve the transportation efficienc [15-16].

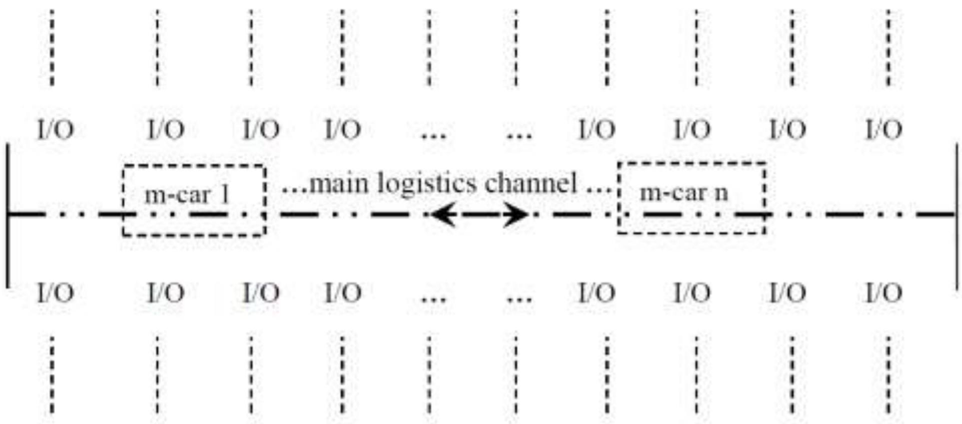

Fig. 5 Schematic diagram of parent vehicle and interface node of main logistics channel

According to the schematic diagram of parent vehicle and interface node in the main logistics channel above, for the horizontal movement path, several parent vehicles are scheduled on the main channel closed at both ends, and the operation task of loading or unloading child vehicles is started or stopped at the I / O interface nodes on both sides of the main channel. Therefore, the scheduling parameters are defined as follows according to this task process:

(1) Define the parent vehicle loading sub vehicle interface node as Pj, the parent vehicle unloading sub vehicle interface node as Ky, and the parent vehicle number is the same as that in the previous section bn;

(2) The system dispatching can know the real-time position of the conveying mother car on the main channel at any time, which is a necessary condition for dispatching all mother cars;

(3) All mother cars on the main channel can move forward and backward in both directions;

(4) When the parent vehicle reaches the I / O node, it can load or unload the child vehicle immediately;

(5) At the same stage, one parent vehicle can only load one sub vehicle to perform operation tasks;

(6) The operation of all mother cars on the main channel shall take the principle of proximity as the

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priority;

According to the above analysis assumptions, the optimal scheduling of parent cars in the main channel can be described as: there are n parent cars b1, b2... bn, on the main logistics channel, and there are c operation tasks i1PjKy, i2PjKy ... icPjKy, which operate within Tm time, so that all parent cars can complete the most loading and unloading sub car handling tasks, the least idling and the most composite operation of steel coil access, At the same time, the starting and stopping times of the mother car and the waiting time for mutual avoidance between the mother cars are reduced to minimize the handling time. According to the above parameter assumptions and optimal dispatching description, the mathematical model of parent train dispatching operation rules can be established, and the expression is as follows:

(1) Expression of the shortest waiting time for avoiding parking between parent vehicles in the main channel:

$$min \sum_{i=1}^{c} twb, i \tag{8}$$

i is the job task number, i = 1,2 ... c;

(2) Expression for the shortest time of starting, stopping, acceleration and deceleration during parent vehicle operation:

$$min \sum_{b=1}^{n} tab, i \tag{9}$$

b is the number of parent vehicle, b=1,2...n;

(3) Di and Dmini respectively represent the distance and the shortest distance from the parent vehicle to the interface node to load or unload the child vehicle when executing the i-th job task; Di-Dmini > 0, which ensures the effectiveness of the parent vehicle in carrying out the operation task;

(4) Db and Dminb-1 respectively represent the distance and the shortest distance from the parent vehicle to the interface node to load or unload the child vehicle when the parent vehicle operation tasks of b-th and b-1-th are performed; Db-Dminb-1 > 0, which ensures the movement interval between multiple parent vehicles during operation tasks;

$$makespan = min\{C(m_c, n)\} = min \sum_{s=1}^{3} \left(tm_{s,i,b,a} + tm_{s,i,a,b} + min \sum_{i=1}^{c} tw_{a,b,i} + min \sum_{i=1}^{n} ta_{s,b,i} + tz_{s,i,a,b} + tz_{s,i,b,a} + tz_{s,i,a} \right) \tag{10}$$

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(5) Xib∈｛0, 1｝;i=1,2,...c;b=1,2,...n;Indicates the status of the i-th job task executed by the b parent vehicle, Xib = 1 indicates that the job task is in progress, otherwise it is 0.

(6) Ti+1bs indicates the start time of the i+1 operation task of the b parent vehicle, Tibe indicates the end time of the i-th operation task of the b parent vehicle, Ti+1bs ＞Tibe It means that one parent vehicle can only carry out one operation task at the same time. The next task can only be carried out after completing the current task.

Based on the above established mathematical model of parent vehicle operation principle of main channel in horizontal path direction, and according to the iterative formula of flow shop scheduling principle in the previous section, the different stages of single operation and composite operation objective function are integrated to obtain the following horizontal path objective function of logistics system:

$$makespan = min\{C(m_c, n)\} = min\sum_{s=1}^{3} (tm_{s,i,b,a} + tm_{s,i,a,b} + min\sum_{i=1}^{c} tw_{s,b,i} + min\sum_{b=1}^{n} ta_{s,b,i} \quad (11)$$

s: Number of operation stages;

a: Sub car number, value range (1, m);

b: Parent vehicle number, value range (1, n);

i: Job task number, value range (1, c);

tms, i, b, a: The time from the current position to the interface position of the sub vehicle in phase s for the b parent vehicle loading the i-th operation task for the system, that is, the no-load operation time Tm1 of the parent vehicle. If the parent vehicle does not need to enter the child vehicle at this stage, this value is 0;

tms, i, a, b: the time taken by the b parent vehicle loading the i-th task for the system from the interface position of the child vehicle to the target interface position in phase s, that is, the loading operation time Tm2 of the parent vehicle. If the parent vehicle does not need to enter the child vehicle at this stage, this value is 0;

ts, i, b: The starting, stopping, waiting and avoidance time of the B parent vehicle loading the i-th operation task for the system in phase s, that is, the parent vehicle safety detection time and avoidance waiting time TM3, are also the sum of the mathematical model expression (1) and expression (2) of the parent vehicle dispatching operation rule. If the parent vehicle does not need to enter the child vehicle at this stage, this value is 0;

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After superposition and integration of the scheduling mathematical models in the horizontal and vertical directions of the system operation tasks, the scheduling optimization objective function of the sub parent vehicle operation rules of the final intermediate warehouse logistics system is obtained:

Total constraints:

(1) For the child vehicle and parent vehicle, each task can only have one priority, pg, i is the priority serial number:

$$\sum_{g=1}^{c} p_{g,i} = 1; i = 1,2\ldots c \quad (12)$$

(2) Whether the parent vehicle is carried by the sub vehicle in phase s, and its expression is: us, a, b=1, Sub car a uses parent car b in phase s; otherwise us, a, b =0;

(3) Each sub car can only occupy one parent car at the same stage:

$$\sum_{b=1}^{n} u_{s,a,b} = 1; i = 1,2\ldots c; s = 1,2,3 \quad (13)$$

(4) For the child vehicle and the parent vehicle, Di and Dmini respectively represent the distance and the shortest distance from the parent vehicle to the interface node to load or unload the child vehicle when performing the i-th operation task; Di-Dmini > 0, which ensures the effectiveness of the parent vehicle in carrying out the operation task;

(5) For the child vehicle and the parent vehicle, Db and Dminb-1 respectively represent the distance and the shortest distance from the parent vehicle to the interface node to load or unload the child vehicle during the b and b-1 parent vehicle operation tasks; Db-Dminb-1>0, which ensures the movement interval between multiple parent vehicles during operation tasks;

(6) The system still has, Ti+1bs indicates the start time of the i+1 operation task of the b parent vehicle, Tibe indicates the end time of the i operation task of the b parent vehicle, Ti+1bs ＞Tibe indicates that only one operation task can be performed by a parent vehicle at the same time, and the next task can be performed only after the current task is completed.

(7) Xib∈｛0, 1｝; i=1, 2,...c; b=1, 2,...n; Indicates that the parent vehicle b is in the state of executing the i-th job task, Xib=1 indicates that the i-th job task is in progress, otherwise it is 0.

VI. EXAMPLE VERIFICATION

Since Johnson opened the research of scheduling problem, scheduling problem has been an extremely difficult NP problem of combinatorial optimization. The scheduling model has changed from simple to

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complex, and its algorithm has developed from the initial mathematical method to the heuristic intelligent algorithm for large-scale computer application with the change of scheduling model [17]. At present, the methods to solve scheduling problems are mainly divided into two categories: exact method and approximation method. In this paper, expert intelligent evolutionary algorithm (EGA), one of the mature approximate iterative methods in computer application, is used to solve the example based on the hybrid flow shop scheduling model [18]. The algorithm is not repeated, but the effectiveness of the scheduling model is verified by the algorithm, and the calculation and Simulation of the scheduling model is realized by MATLAB software. During the simulation experiment, the data running environment is: Windows 7 operating system; Intel core i7, 2.8 Ghz CPU; 8GB RAM.

In the case of the logistics system of multiple parent cars in the cold rolling intermediate depot of a steel plant, as shown in Figure 6, the number of sub cars in the vertical buffer channel and parent cars in the horizontal main channel are 14 and 8 respectively; The storage operation, retrieval operation and joint access operation of intermediate warehouse logistics system are regarded as different processes of workpiece processing in flow shop.

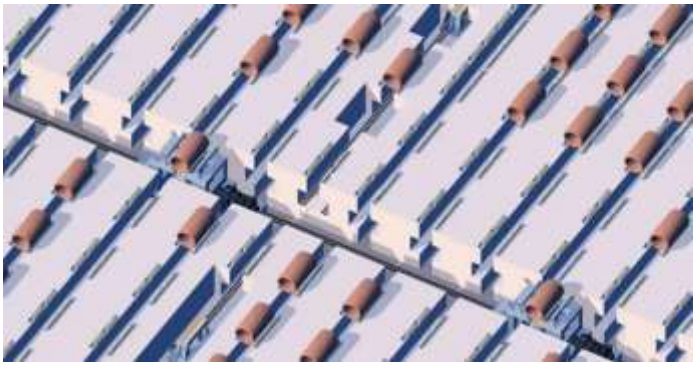

Fig. 6 partial diagram of multi multi-car conveying system in cold rolling intermediate Depot

Select 10 intermediate warehouse logistics access volume tasks in a period of time for simulation analysis, and assume the time of each task in different processes according to the empirical value, as shown in Table 1 access operation process time table.

TABLE I. Time table of access operation

Task number	**Procedure 1 (sub car taking coils)**	**Procedure 2 (mother car taking coils)**	**Procedure 3 (sub car storing coils)**	**Procedure 4 (mother car storing coils)**
1	36 s	40 s	0 s	0 s

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2	30 s	42 s	50 s	60 s
3	30 s	35 s	35 s	40 s
4	40 s	35 s	30 s	35 s
5	0 s	0 s	45 s	40 s
6	35 s	40 s	35 s	35 s
7	25 s	30 s	35 s	30 s
8	40 s	35 s	0 s	0 s
9	50 s	45 s	55 s	25 s
10	30 s	35 s	40 s	30 s

According to the index parameters of flow shop scheduling principle, the main data of production logistics in the intermediate warehouse of an example steel plant are divided into:

i=machine number in the machine set;

m=total number of machines;

j=workpiece number in the workpiece set;

n=total number of workpieces;

pj, i=processing time of workpiece j on machine i;

k=workpiece number after workpiece sorting;

xj, k= decision variable.

Combining the above parameters with the sub parent vehicle access process and equipment quantity of the intermediate warehouse multi child parent vehicle logistics system studied in this paper, table 2 is the corresponding table of scheduling model parameters.

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TABLE II. Corresponding table of dispatching model parameters

Operation No.(k)	**1((sub car taking coils)**	**2(mother car taking coils)**	**3(sub car storing coils)**	**4(mother car storing coils)**
Number of machine (i∈m)	14	8	14	8
Access task(j∈n)	10	10	10	10

In the process of solving the hybrid flow shop scheduling problem, the evaluation of the merits and faults of the scheduling plan needs to be judged by a certain objective function. The objective function of the commonly used evaluation indexes has the minimum makespan, the smallest machine load, the smallest total machine load and the smallest advance or lag time. In this paper, two typical indexes, the minimum maximum completion time and the minimum total machine load, are used to verify the effectiveness of the multi child parent vehicle scheduling model in the intermediate warehouse.

The minimum of maximum completion time is one of the key indicators to measure the scheduling scheme, which directly reflects the production efficiency of the system. The expression of its function is:

$$F1 = min(max(cj)); 1 < j < n \tag{14}$$

When the maximum completion time is the same, the total time of all machines is the smallest, which is one of the most extensive evaluation indexes of flow shop scheduling. The expression of its function is:

$$F2 = min(\sum_{i=1}^{m} \sum_{j=1}^{n} p_{ij} \, x_{ij}) \tag{15}$$

Run MATLAB software on the computer, and use expert intelligent evolutionary algorithm EGA to iteratively check the scheduling model function of multi child mother car system in the intermediate depot. The upper limit of iteration times in the calculation and operation process is 150. See the appendix for the main program of the algorithm. Obtain the trend chart of the measurement index of the scheduling function: as shown in Figure 7, the trend curve of the maximum completion time F1 and figure 8, the trend chart of the total machine load F2. The abscissa in the figure is the iteration times of the scheduling model index checking, and the ordinate is the maximum completion time and total machine load respectively.

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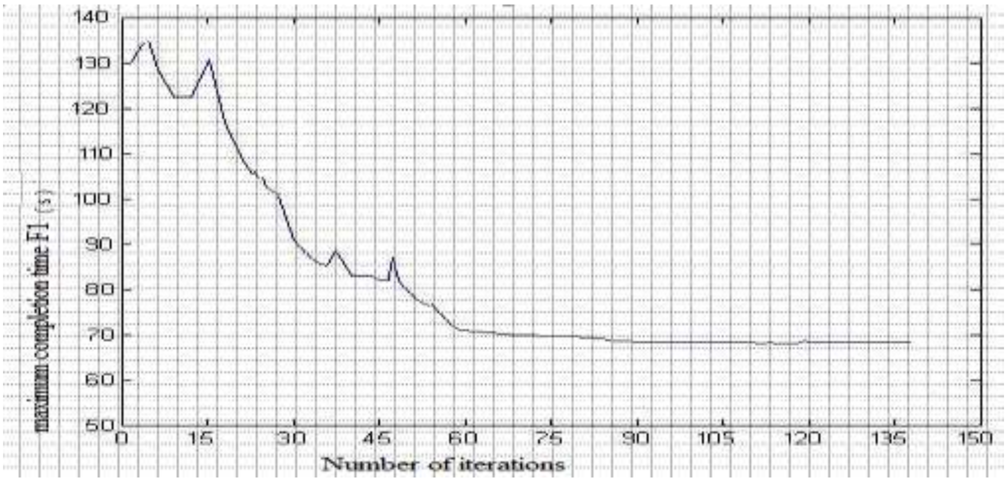

Fig 7: Trend curve of maximum completion time F1

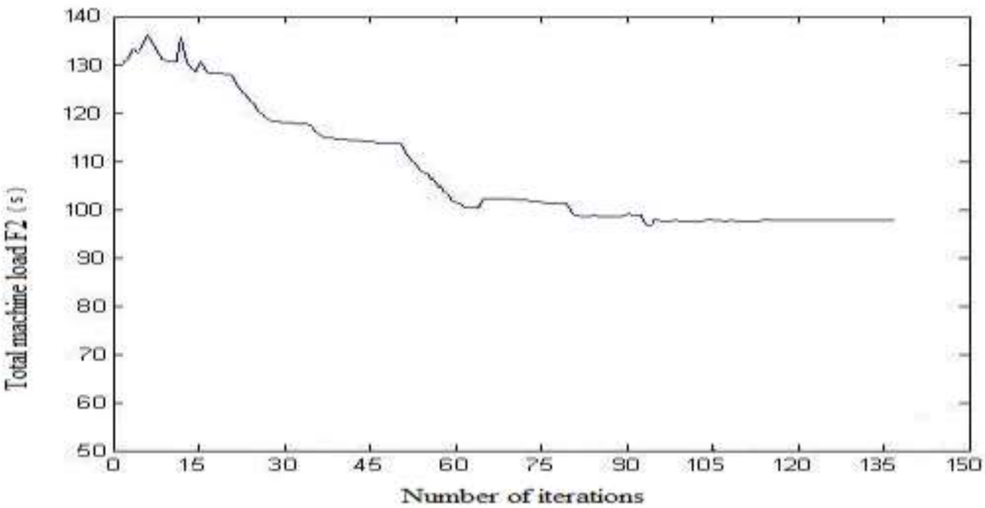

Fig 8. Trend curve of total machine load F2

It can be seen from the above figure that the values of the two evaluation indexes tend to converge in the early stage of model checking, which shows that the scheduling model is solvable and effective; In the middle and later stages of the iteration, the values of the two evaluation indexes fluctuate and tend to be stable at the end, which shows that the final numerical result of the model not only obtains the optimal solution, but also has strong wide area search ability to avoid falling into local optimization, so it can truly and comprehensively reflect the final solution of the whole scheduling model; As the number of iterations increases, the makespan F1 and the total machine load F2 tend to be stable. After checking the evolution to 110 times, the evaluation index values of the scheduling models converge within 70s and 100s respectively. These two key indexes have good convergence and synchronization, which also proves that the scheduling model can truly and accurately express the multi child parent vehicle scheduling system of intermediate Depot Based on hybrid flow shop theory.

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Fig. 9 extracts the optimal solutions of three groups of multi child parent vehicle transportation scheduling models based on the intermediate warehouse of the hybrid flow shop. The content of each row in the table is the number of child vehicles and parent vehicles called by the task sequence in different access processes. The unit of the maximum completion time F1 and the total machine load F2 of the two evaluation indexes of the scheduling model is seconds. It can be seen that most of the three groups of optimal solutions have little difference in the call of child and parent vehicles in each access link. They basically use the adjacent child vehicles and parent vehicles for scheduling operations, avoiding multi vehicle operation conflict and long-distance call as far as possible, indicating that the scheduling model has good local optimal search performance. At the same time, through the optimal solution sample, it can be found that when the maximum completion time F1 is the smallest, the total machine load F2 is not the smallest, indicating that in order to obtain the minimum completion time, the machines of the scheduling system will bear more loads and participate in the deployment operation to improve the operation efficiency of the whole system.

Sample of optimal solution for scheduling model of multi-vehicle transportation system in intermediate warehouse based on hybrid flow shop

		Access task serial number										Total	Maximum
	Equipment number	1	2	3	4	5	6	7	8	9	10	machine	Completion Time
Optimal solution 1	1 (Sub car coiling)	5	3	4	2		3	5	6	9	1	94	70
	2 (Mother car coiling)	2	1	4	6		2	4	5	7	2		
	3 (Sub car storage)		4	6	8	1	4	3		11	1		
	4 (Mother Car Storage)		3	2	5	2	1	4		6	1		
Optimal solution 2	1 (Sub car coiling)	4	3	5	7		8	2	4	12	10	97	68
	2 (Mother car coiling)	1	2	3	5		3	5	2	7	5		
	3 (Sub car storage)		4	7	8	8	5	10		13	14		
	4 (Mother Car Storage)		3	4	5	3	2	7		6	8		
Optimal solution 3	1 (Sub car coiling)	3	6	8	4		4	9	12	10	14	98	68
	2 (Mother car coiling)	2	3	4	1		2	5	6	6	8		
	3 (Sub car storage)		8	10	10	5	7	6		12	9		
	4 (Mother Car Storage)		4	5	6	2	3	4		7	6		

Fig. 9 optimal solution sample of scheduling model checking

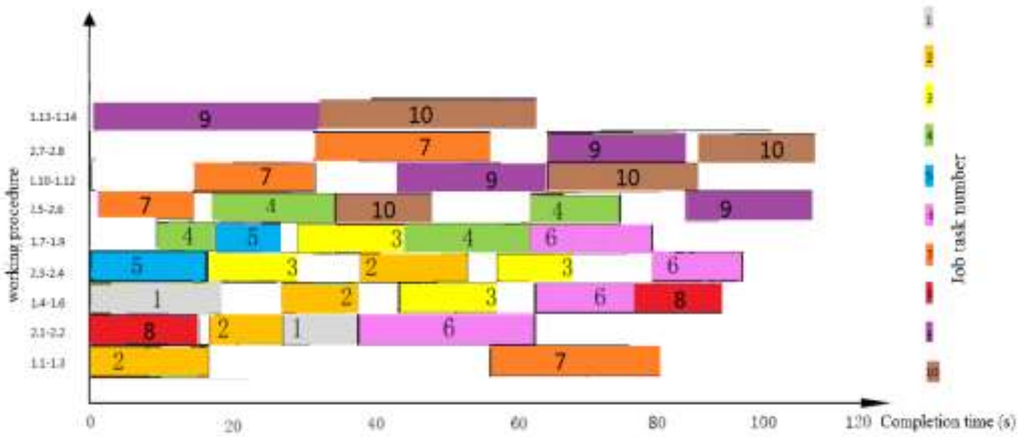

Fig 10: Gantt chart of job scheduling based on hybrid flow shop

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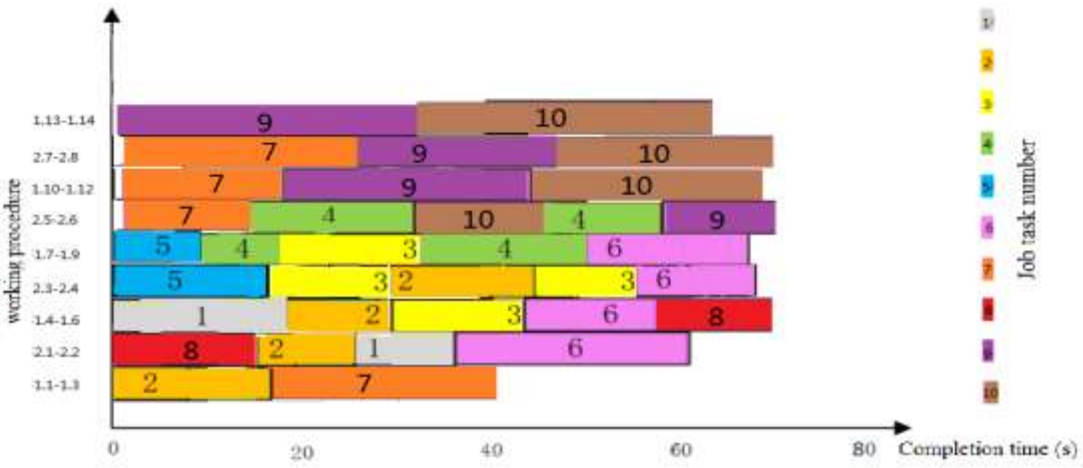

Fig 11: Gantt chart of time sorting scheduling job

In order to more intuitively reflect the processing of access job tasks in different processes and different machines, the Gantt chart is drawn through the optimal solution obtained by the scheduling model for comparison. Taking the optimal solution 2 as an example, the Gantt chart based on Hybrid Flow Shop Scheduling in FIG. 10 and the Gantt chart scheduled in time series in FIG. 11 are drawn, and the abscissa in the chart is the job completion time, The ordinate is the machine number, i.e. 14 sub cars and 8 parent cars. The numbers of 10 different colors represent different tasks to be processed. It can be seen from the figure that the starting processing time of each task. Compared with the conventional time sequencing scheduling, this scheduling model improves the connection between the front and rear processes, reduces the waiting time of each machine, ensures the continuity of the operation, effectively makes use of the idle time of the child and parent vehicle, improves the operation efficiency of the multi vehicle conveying system and shortens the total completion time.

VII. CONCLUSION

According to the characteristics of the cross compound configuration of multiple sub vehicles and multiple parent vehicles in the intermediate warehouse logistics transportation system, this paper analyzes the joint operation of storing / taking steel coils and simultaneously accessing steel coils, refines and decomposes them, formulates the system operation rules and operation path expression, and establishes the system scheduling optimization mathematical model based on the iterative principle of flow shop processing, The objective function of the shortest time sub parent vehicle scheduling optimization of the intermediate depot logistics system is obtained, and an example of the logistics scheduling system is verified and analyzed. It is proved that the hybrid flow shop model is effective for the scheduling optimization of this kind of multi sub parent vehicle logistics system, and provides an intelligent and efficient scheduling solution for the production logistics of the intermediate depot in the field of metallurgical heavy load, it also opens up a new idea for the research of compound scheduling model of this kind of multi vehicle system in the future. However, due to the limitations of my research time and personal ability, the scheduling planning content studied in this paper, especially the path conflict prevention, is worthy of further research in depth and breadth. I hope it can be continuously improved in combination with multiple actual cases in the future.

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